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LACIE-C00200 (REV. A)
VOLUME III
JSC-11340

LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

CROP INVENTORY
LARGE AREA
EXPERIMENT
LACIE

NASA NOAA USDA

Level 3 Baseline

YIELD ESTIMATION
SUBSYSTEM (YES) REQUIREMENTS

NOTICE: THIS IS A BASELINED LEVEL 3 DOCUMENT CONTROLLED BY THE LACIE LEVEL 3 CHANGE CONTROL BOARD. ANY PROPOSED CHANGES SHOULD BE DOCUMENTED ON AN RECP FORM AND TRANSMITTED TO R. B. MACDONALD, LACIE MANAGER, NASA-JSC, CODE TF, HOUSTON, TEXAS 77058.

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

SEPTEMBER, 1976

REVISIONS

REV LTR	CHANGE NO.	DESCRIPTION	DATE
		BASELINE ISSUE (Reference CCBD #III-0001, dtd December 16, 1974)*	12-16-74
A	6M0037	Major revision due to the extensive nature of LACIE change notices to this document.	9-23-76

LIST OF EFFECTIVE PAGES

The current status of all pages in this document is as shown below:

Page No.	LACIE Change Date	Authorizing CCBD No.
ii through ix	Revision 9-22-76	6M0037
1-1 through G-2	Revision 9-22-76	6M0037

FOREWORD

Efficient management of the Large Area Crop Inventory Experiment (LACIE) dictates that effective controls of project activities be established. To provide a basis for effective control, documentation will be prepared, baselines will be established, and changes to the baselines will be subsequently controlled by the proper management levels.

The specific control documents which will be used are defined in the LACIE Project Plan, LAP01. All elements of the LACIE Project must adhere to these baselined control documents, and, where it is considered that the requirements should be changed, the proper change request, accompanied by a full justification, must be submitted to the proper management level in accordance with established procedures. These documents will be maintained current by change notices and revisions, as required. Each change notice and/or revision will reference the applicable Change Control Board Directive (CCBD) which approved the change.

This document LACIE-C00200, Volume III (Rev. A) defines the LACIE Yield Estimate Subsystem (YES) requirements and has been prepared in accordance with the "Instructions for Preparation of LACIE Requirements Documents", LACIE-00100, Revision C, dated November 20, 1974. "Full-Up System," as used in this document, is defined as the system required to accomplish LACIE Phase II. In general, the approach used in each section is to first specify the requirements of the Full-Up System and then to specify the requirements of any interim systems by reference to specific paragraphs in the Full-Up System requirements sections of the document. The LACIE Project Phases are defined in the LACIE Project Plan, LAP01.

The YES functional responsibilities provide an opportunity to use Phase I of LACIE as a period for research into new techniques, procedure development, and testing, with total integration into the LACIE Application Evaluation System beginning with Phase II. However, where possible during Phase I in the course of developing and testing of the operating procedures, YES will utilize the LACIE supporting facilities. It is likely that in Phase I the YES will be able to predict the yield for portions of several of the countries considered in the study. Where this capability exists, it will be tested and will provide a test of the supporting systems to be relied upon in Phase II. The National Oceanic and Atmospheric Administration (NOAA) has

prime responsibility for this subsystem, with support from the United States Department of Agriculture (USDA) and from the National Aeronautics and Space Administration (NASA). The yield prediction models may be operated at the Lyndon B. Johnson Space Center (JSC) or at Environmental Data Service (EDS) for integration into the Crop Assessment Subsystem (CAS) at JSC. The models should be implemented at both JSC and EDS to permit their use at one facility for test and development and at the other for operations, with the test facility always available as backup for the near real-time operational facility.

In comparison with CAMS, the operation of the yield models require very little in computer storage capacity or operating time. If high priority were assigned to this task, this subsystem computer support could easily become an off-line system.

Specific objectives must be met to perform the general objectives of YES. To meet these specific objectives, certain tasks must be performed. The requirements listed here are the services, facilities, manpower, and applications of technology necessary to perform these tasks. Although not stated, it is implied that the YES will, at the end of LACIE, be providing the best system possible for yield prediction for followup programs. Consequently, the YES will have continuous development, research, and pilot requirements through the life of the project.

The organization responsible for the implementation of each requirement defined in this document is specified on an individual requirement basis. Where the implementation responsibility applies to the complete section, the implementation responsibility is specified after the section title. A "section" for the purposes of designating implementation responsibility is defined as being any numbered paragraph and all subparagraphs. Where different implementation responsibilities apply to different portions of a section, the implementation responsibility is specified on an individual paragraph or sentence basis, as applicable. All implementing organizations designated shall accomplish their implementation activities in accordance with the requirements specified herein.

R. B. MacDonald
Manager, Large Area Crop Inventory Experiment (LACIE)

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GLOSSARY

ADP	Automatic Data Processing
Agro-met	Agricultural-meteorological
ASVB	Applications System Verification Branch
CAMS	Classification and Mensuration Subsystem
CAS	Crop Assessment Subsystem
CCT	Computer-compatible tape
COD	Center Operations Directorate (NASA)
CPU	Central Processing Unit
DAPTS	Data Acquisition, Preprocessing, and Transmission Subsystem
DR	Discrepancy Report
DSAD	Data Systems and Analysis Directorate (NASA)
EDS	Electronic Data System
EOD	Earth Observation Division (NASA)
EDS	Environmental Data Service (NOAA)
EOF	End-of-file
ERIPS	Earth Resources Information Processing System
ERTS	Earth Resources Technology Satellite
FSO	Facilities Support Office (NASA)
Full-up system	The system required to accomplish LACIE Phase II
GSFC	Goddard Space Flight Center (NASA)
ICD	Interface control document
IE	Information evaluation

IMS	Information Management System
Interim system	System requirements to accomplish subphases of LACIE Phase I excluding subphases IA and IB.
I/O	Input/Output
ISRRS	Information Storage, Retrieval, and Reformatting Subsystem
JSC	Lyndon B. Johnson Space Center
LACIE	Large Area Crop Inventory Experiment
LACIE PO	LACIE Project Office
LEC	Lockheed Electronics Company, Inc.
MET	Meteorological
MSS	Multispectral Scanner
MTU	Magnetic tape unit
NASA	National Aeronautics and Space Administration
NDPF	NASA Data Processing Facility
NOAA	National Oceanic and Atmospheric Administraiton
PDR	Problem Defect Report
PFC	Production Film Converter
QA	Quality Assurance
RTCC	Real-Time Computer Complex
RTEB	Research, Testing and Evaluation Branch (NASA)
S&AD	Science and Applications Directorate (NASA)
SAT	Satellite
SPE	System Performance Evaluation (subsystem)

TBD	To be determined
U.S.A.	United States of America
USAF-ONC	United States Air Force Operational Navigational Charts
USDA	United States Department of Agriculture
U.S.S.R.	Union of Soviet Socialist Republics (Russia)
WMO	World Meteorological Organization
YES	Yield Estimation Subsystem

1.0 FUNCTIONAL RESPONSIBILITIES

1.1 GENERAL

The primary responsibility of the YES will be the design, implementation, testing, and operation of agricultural-meteorological (agro-met) models to obtain yield estimates for each of a number of locations to be specified by the CAS. In addition, YES will provide meteorologically induced signature-extension information and adjustments to normal crop calendar dates. YES is responsible for the acquisition, standard preprocessing, and transmission of all meteorological data required for LACIE.

1.2 Specific

- Select, redesign, implement, and operate agro-met models for selected areas in selected countries to obtain yield estimates for the research, test and evaluation effort.
- Provide to other subsystems crop calendar variations and limits to signature extension because of meteorological conditions over the United States and Canada.
- Test and evaluate agro-met modeling procedures to be implemented during Phase II.
- Assimilate requirements for the data, acquire the data, preprocess the data and transmit the data to the Information, Storage, Retrieval and Reformatting Subsystem (ISRRS).

In Phase II, YES will

- Improve and operate the agro-met models to obtain yield estimates for each of a number of locations to be specified by the CAS. The yield model will consist of yield estimates based on objective agro-met yield predictions using meteorological inputs obtained at ground meteorological stations in the global World Meteorological Organization

(WMO) network. These estimates may be modified interactively using information synthesis techniques to incorporate ancillary agricultural and meteorological information.

- Provide operational support to other subsystems for adjustment of sampling periods to account for the meteorological conditions that prevail during the current crop year.

- Provide other subsystems with evaluation of the effects of weather on extension of signatures from one region to another.

- Assimilate requirements for the data, acquire the data, preprocess the data and transmit the data to the Information, Storage, Retrieval, and Reformatting Subsystem (ISRRS).

2.0 APPLICABLE DOCUMENTS

The following documents are applicable to the extent specified herein:

1. Goddard Space Flight Center (GSFC)/JSC Interface Control Document (date to be determined).

2. NASA/NOAA/USDA LACIE Interface Control Document (to be written).

3. Instructions for Preparation of LACIE Requirements Document, LACIE-00100, Revision C, dated November 20, 1974.

3.0 FUNCTIONAL FLOW DIAGRAMS

Diagrams showing the development, design, and operation of the YES are given in figures 1 and 2, respectively.

3.1 YIELD ESTIMATION SUBSYSTEM DEVELOPMENT DESIGN

3.2 YIELD ESTIMATION SUBSYSTEM OPERATIONS

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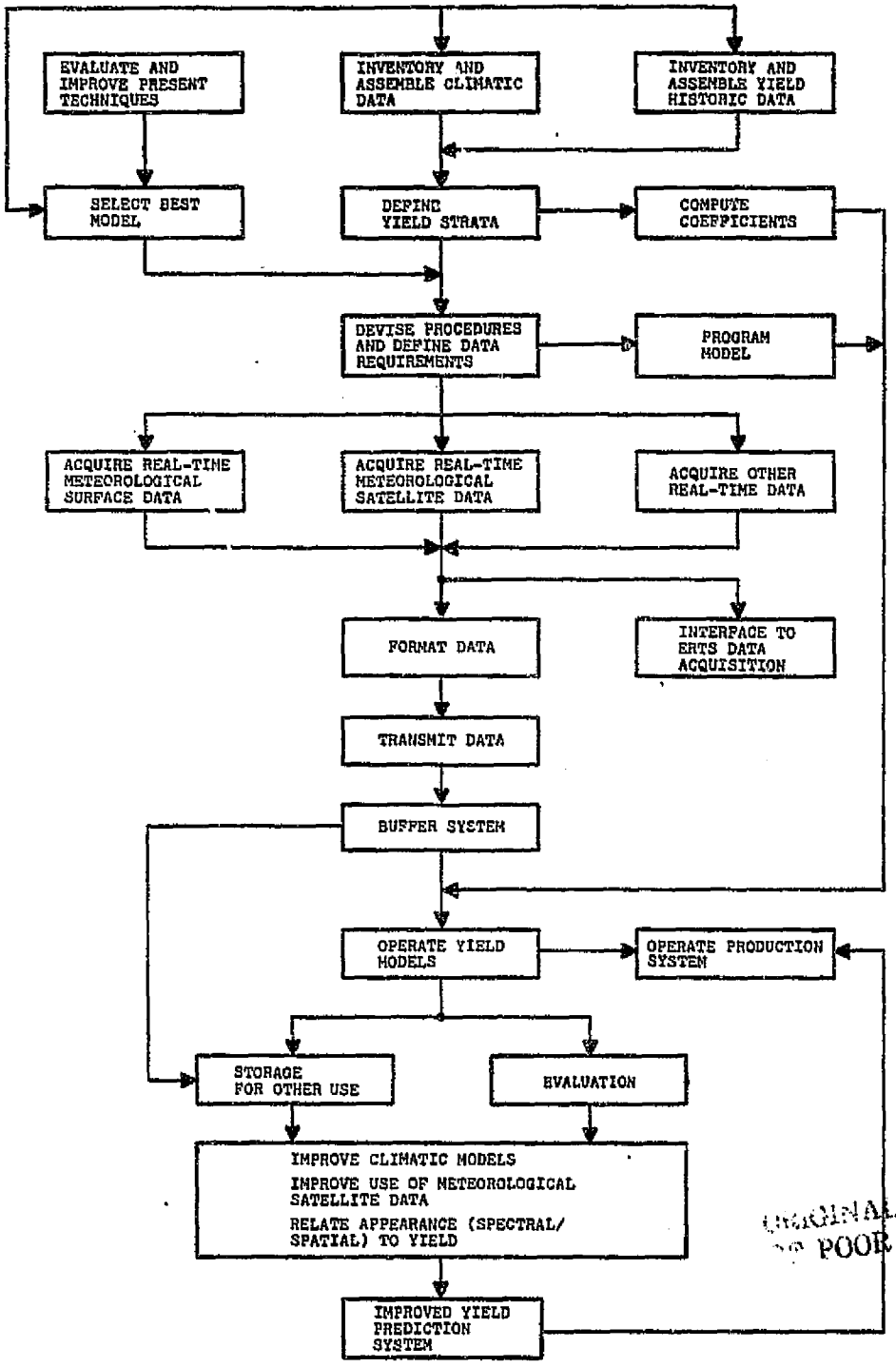

Figure 3-1. – Diagram of development design of the Yield Estimate Subsystem.

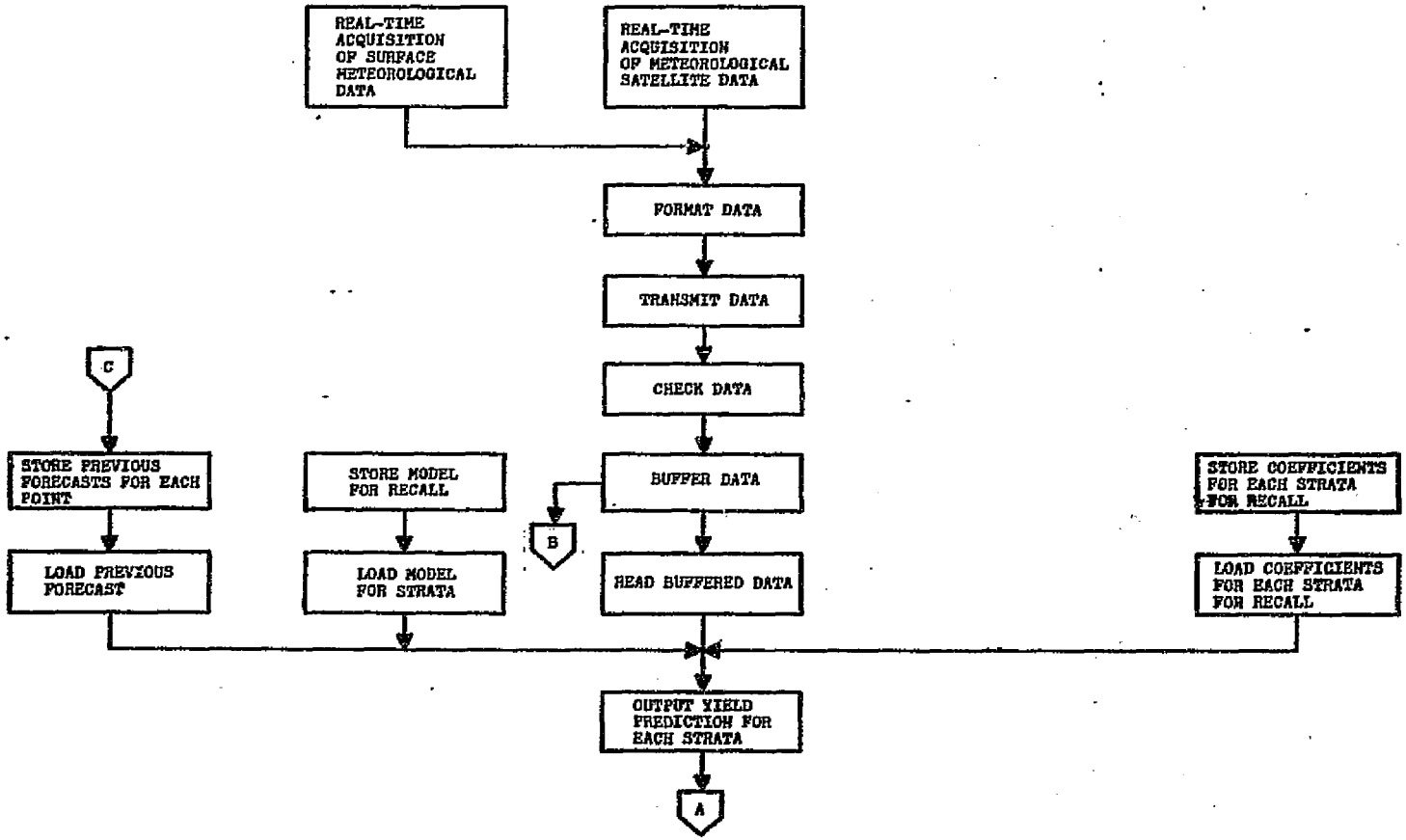

Figure 3-2. — Diagram of operations of Yield Estimate Subsystem.

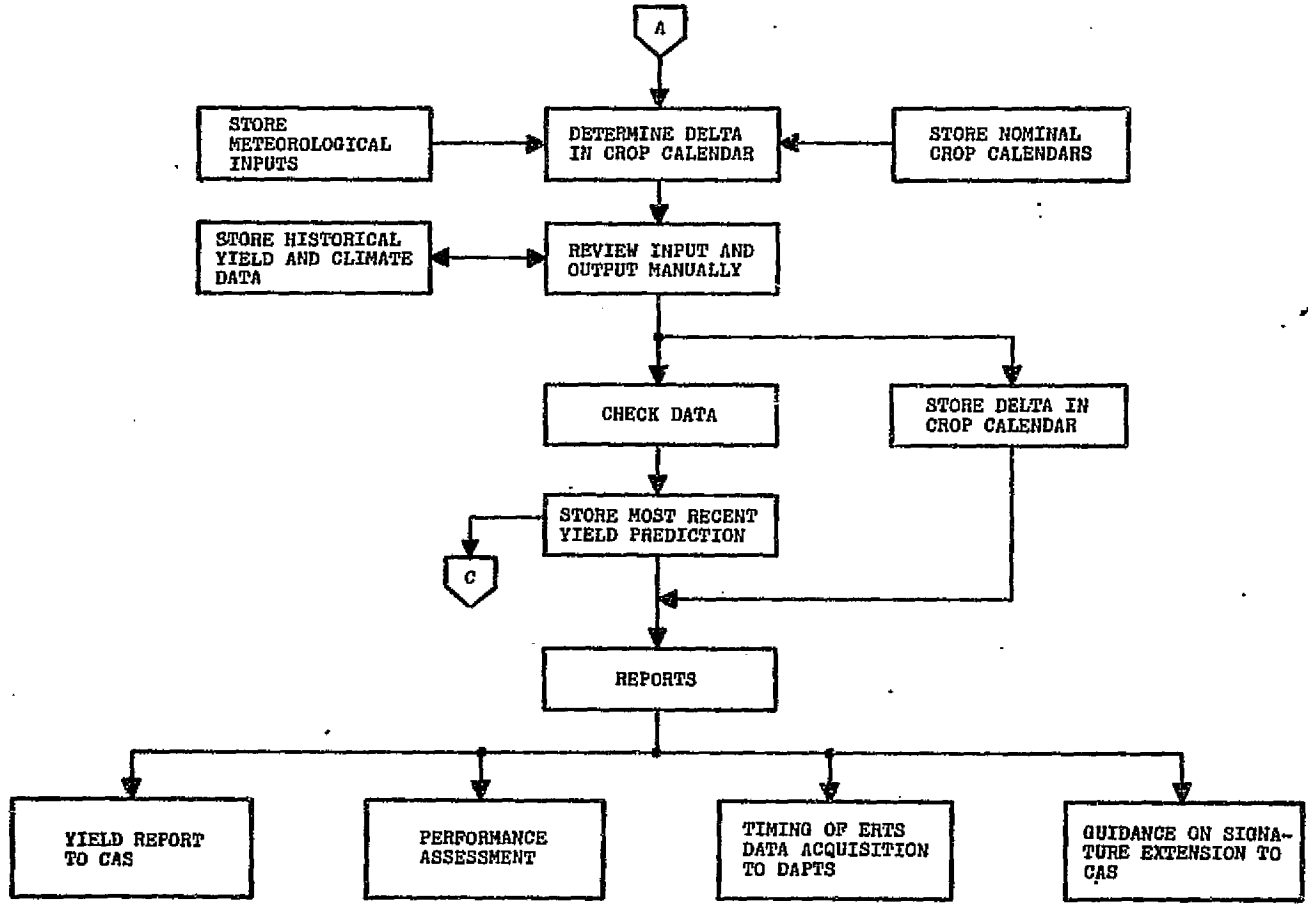

Figure 3-2. – Diagram of operations of Yield Estimate Subsystem – Concluded.

4.0 SUBSYSTEM REQUIREMENTS (CONSOLIDATED)

4.1 FULL-UP SYSTEM

4.1.1 Development

In order for YES to meet its functional responsibilities, the following development must take place.

4.1.1.1 Development of yield models. Yield models that predict the yield of wheat for specific points within strata for a large part of the wheat growing regions of the world must be developed. This development, which is a function of the meteorlogical conditions as indicated by routinely transmitted meteorlogical reports, consists of:

a. Determination of the boundaries of the strata such that within a stratum cultural and environmental factors are fairly uniform.

b. Selection of the parameters to be used for yield prediction (these may vary according to time and place).

c. Selection of the forms of the models (models may vary with phases of the growing season and from place to place).

d. Determination of coefficients to be used with the models.

e. Programming of models for computer operations.

f. Testing of models.

(Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

4.1.1.2 Normal crop calendar definition. Normal crop calendars for wheat and its confusion crops must be defined for each yield stratum and points within strata. The crop calendar must be defined by relating the development of a crop to progression along a numerical scale and in terms of

day of the year. The standard deviations in days about the mean for several points in the growing season are required (Required by YES; Category 2; Implementation Responsibilities: DAPTS/NOAA/USDA).

4.1.1.3 Crop calendar adjustment. Procedures for computing the departure of the current year's calendar from the mean calendar for specified points, based on the meteorological conditions for the current year up to that time, will be required (Required by YES; Category 2; Implementation Responsibilities: YES/NOAA).

4.1.1.4 Data transmission system. A data transmission system that permits interception of pertinent meteorological data from the world wide weather communication system and transmission into that part of the Information Storage, Retrieval, and Reformatting Subsystem (ISRRS) which supports YES must be designed and implemented by July 1, 1975 (Required by YES; Category 2; Implementation Responsibilities: YES/NOAA).

4.1.1.5 Information Storage, Retrieval, and Reformatting System. An information, storage, retrieval, and reformatting system structured to handle the input and output data referred to in sections 5.0 and 6.0 and the operations described in section 4.1.2 must be designed and implemented no later than August 1, 1975 (Required by YES; Category 2; Implementation Responsibility: ISRRS).

4.1.1.6 Performance assessment plan. A performance assessment plan for YES must be designed and implemented no later than August 1, 1975 (Required by YES; Category 2; Implementation Responsibility: YES/CAS).

4.1.2 Operations

In order for YES to meet its functional responsibilities operationally, the following functions must be performed:

4.1.2.1 Data handling — YES. The specific meteorological data to be used as inputs into the family of yield models (both data and model inputs) are described in section 5.1.1.5. These data must be pulled out of the stream of meteorological data routinely transmitted in international communication, filtered to exclude unnecessary information, and transmitted to the point of operation of the models (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

4.1.2.2 Data receipt — YES. The data received at the location of the model operations must be checked for drop-outs in transmission and formatted in acceptable manner for storage and buffering. This requirement represents an interface between the ISRRS and operating transmission system of NOAA. It could prove to be complex and should be approached early in Phase I of the project (Required by YES; Category 2; Implementation Responsibility: YES/NOAA/ISRRS).

4.1.2.3 Data buffering and storage — YES. After acceptance at the point of model operations, the data will be buffered for insertion into the models and stored for recall upon demand at any time during the current crop year. Instant recall is not required — hence tape storage is suitable because the data will be input in a batch mode rather than as a continuous stream (Required by YES; Category 2; Implementation Responsibility: ISRRS).

4.1.2.4 Meteorological yield model operations. Periodically (at least monthly) and on demand during Phase II, the yield models will be operated by loading the models, its coefficients, and previous forecasts if required. The meteorological data will be read from the buffer according to yield strata. Yield forecasts for individual stations will be made based on normal or predicted weather from time of forecast to harvest. The specifics of these inputs are given in section 5.1.5.3. Forecasts of yield will be made at each point for which meteorological data have been assimilated over the yield strata. Operating the model for another stratum may require the loading of a different set of algorithms and coefficients. As the season progresses, it is possible that the algorithms and coefficients within a stratum will change. As noted in section 5.1.5.3, up to five such changes will be allowed. Interactive yield

prediction operations with the models must be accomodated to permit the computation of an envelope of possible yield based on hypothetical weather conditions. Such use of the models will not require storage of its output in ISRRS (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

4.1.2.5 Crop calendar adjustment operation. In order to operate the adjustable crop calendar, it is necessary that the normal crop calendars for specific points be available for recall. These calendars will be indexed by meteorological station and yield strata and graphical plot, or by an algorithm. Because the normal stage of crop development must be depicted on a defined numerical scale as a function of day of year and crop growth, indices (based on meteorological data) must be available for a selected number of meteorological stations. The meteorological data for the adjustment of the crop calendar must be read periodically (at least monthly), and the ability to read upon demand must also be available. Output will be normal crop calendar for the point, the normal phase of the crop the day of operation (in an optional mode), and the delta in days for the specific case run. Normal crop calendars for confusion crops will be given for each stratum, but the delta will be assumed to be the same as in wheat (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

4.1.2.6 Output review - YES. To test their consistency, the outputs of the yield models and adjustable crop calendar (described in section 6.0) must be reviewed by analysts familiar with the models and their inputs. The reviewer must be able to recall any inputs that went into the forecasts and to change obvious erroneous values and restructure model operations as required (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

4.1.2.7 Output storage - YES. After review, the output of the crop calendar delta computation and the yield model predictions will be sent to the ISRRS for storage and recall by other subsystems. Recall will provide yield reports to the Crop Assessment Subsystem (CAS); reports advising the Classification and Mensuration Subsystem (CAMS) and the Data Acquisition, Preprocessing, and Transmission Subsystem (DAPTS) as to the timing of ERTS acquisitions;

reports to CAMS on signature extension; and, a report to CAS on evaluation of the output and cost determination (Required by YES; Category 2; Implementation Responsibility: ISRRS).

4.2 INTERIM SYSTEM

YES will support the CAS, CAMS, DAPTS, and Research, Testing and Evaluation Branch (RTEB) efforts to interpret the progression of crop development during Phase I. This support will consist of descriptions of normal crop calendars for wheat and othe major crops for the areas to be specified and recommendations for adjusting these calendars according to the year and area of interest, based on subjective techniques. To perform this task, YES will require interim crop calendars for wheat and other major crops for the regions of LACIE operation in Phase I on or before January 1, 1975 (Required by YES; Category 1; Implementation Responsibility: DAPTS).

5.0 SUBSYSTEM INPUT REQUIREMENTS

5.1 FULL-UP SYSTEM

5.1.1 Data Acquisition, Preprocessing, and Transmission Subsystem (DAPTS)

5.1.1.1 Yield and crop progression data. To apply Earth Resources Technology Satellite (ERTS) data for determination of yield and crop progression during Phase II, it is necessary that selected portions of the ERTS-acquired data be made available to YES for remote determination of yield and crop progression developed by the research effort. No special acquisition or preprocessing is anticipated at this time (Required by YES; Category 4; Implementation Responsibility: DAPTS).

5.1.1.2 Field data requirements — YES. Data for the refinement of crop calendars and deltas in crop calendars and for testing yield predictions during Phase I and II must be provided. Thus, it is required that certain crop measurements and observations be made throughout the growing season at U.S.A. intensive test sites. Such observations and measurements on wheat, other cereal grains, and predominate crops will include:

a. For all crops in the area —

- Distinctive growth stages
- Row width
- Estimated ground cover
- Vertical hand-held color slide
- Soil color

b. For all small grains —

- Expanded Robertson biometeorological time scale
- Haun index
- Feeks scal

c. For wheat only – The DAPTS will acquire a completed set of yield determination forms from the USDA after the wheat harvested in each ITS site. The forms will contain the following parameters:

- Winter-kill
- Yield
- Plant dry weight
- Stand quality
- Stressed vs. non-stressed
- Type stress (moisture, disease, etc.)
- Harvest date
- Test site
- Field number

d. For fallow fields:

- Percent weed cover

The observations should be made at 18-day intervals with 30 or more fields to be included in each set. Growing season for winter wheat is defined as date of planting to date of harvest. (Required by YES; Category 2; Implementation Responsibility: DAPTS/USDA).

5.1.1.3 Historic yield data requirements. In order to acquire yield data for developing yield models by regression equations for Phase II use, it is necessary, during Phase I, to acquire historical data on wheat yield for countries involved (1) at the level of consistent greatest detail (i.e., in the United States, at the county level) and (2) for all levels of coarsest detail (CRD, state, national) where available. These data should be gathered according to both per-planted-unit area and per-harvested-unit area and must be available for 2-hour recall at any time during the life of the project. A large portion of the material may be available in published volumes. The data will be needed as follows:

- For the U.S.A., by December 1, 1974
- For Canada, by January 15, 1975
- For the U.S.S.R., by March 1, 1975
- For China, by April 15, 1975
- For other countries, by July 1, 1975

(Required by YES; Category 1; Implementation Responsibility: DAPTS/USDA).

5.1.1.4 Normal crop calendar data. An historic base, which allows planning of ERTS data acquisition and from which significant departures will indicate yield anomalies, must be provided. It will be necessary, prior to the commencement of Phase II, that mean crop calendars for wheat, small grains, and dominant confusion crops be acquired for all countries involved in the study. The calendars should describe mean progress in these crops for areas similar in size to the U.S.A. crop-reporting district. The mean calendar day and the range of days for defined phenological stages of growth is the preferred form for these calendars (Required by YES; Category 1; Implementation Responsibility: DAPTS/USDA).

5.1.1.5 Historic agricultural data. The following are descriptions of the required historic agricultural data in support of the YES.

5.1.1.5.1 Soil maps: Maps indicating major changes in soil type or color are required for all wheat growing regions included in the LACIE. These maps shall be at a scale and projection commensurate with USAF Operational Navigation Charts (ONC's) (Required by YES; Category 2; Implementation Responsibility: DAPTS/USDA).

5.1.1.5.2 Topographic maps: Topographic maps for TBD areas, indicating major surface features at a scale and projection with USAF ONC's are required. The contour interval will be 200 meters or less (Required by YES; Category 2; Implementation Responsibility: DAPTS/FSO).

5.1.1.5.3 A priori probabilities: DAPTS has the responsibility of providing raw input data for the operation of a computer program to compute the priori probability of wheat in a given unit area for CAMS. YES also requires some of this information for crop calendar development to include the probability that, if a segment of land is cropland, the cover class is a member of one or more of the following categories:

a. Winter wheat

b. Spring wheat

c. Wheat

d. Winter cereal

e. Spring cereal

f. Cereal

g. Fall plowed crop

h. Spring plowed crop

i. Harvested winter wheat

j. Harvested spring wheat

k. Harvested spring cereal

l. Harvested winter cereal

m. Harvested fall plowed crop

n. Harvested spring plowed crop

The estimated error in each of the above probabilities is required (Required by YES; Category 2; Implementation Responsibility: DAPTS/USDA).

5.1.1.5.4 Cropping practices: DAPTS shall output to the ISRRS for the CAMS a list of cropping practices for each

of the 4800 sites. Cropping practices are defined as any cultural activities that may create or alter the external morphological characteristics (appearance) of a field or crop signature response as detected by high altitude aircrafts or spacecraft remote sensors. Examples of cropping practices are:

a. Cropping systems or crop rotation systems

b. Tillage practices

c. Irrigation practices

d. Use of fertilizer

e. Use of special purpose crops

- Catch crops
- Cover crops
- Green-manure crop
- Soiling crops
- Silage crops
- Nurse crops

f. Drainage practices

g. Row directions and widths

h. Chemical usage (herbicides, defoliants, etc.)

i. Burning

j. Postharvest field conditions (stacks, bales, plows, etc.)

k. Mowing patterns

l. Grazing

m. Harvesting practices

(Required by YES; Category 2; Implementation Responsibility: DAPTS/USDA).

5.1.1.5.5 Historical agricultural statistics: Wheat acreage for the smallest reporting political subdivision is required. Wheat acreage planted and harvested and total acreage for the smallest reporting subdivision for each LACIE county for the past 15 years is required (Required by YES; Category 1; Implementation Responsibility: DAPTS/USDA).

5.1.1.5.6 Overlap regions: Spring and winter wheat overlap regions in TBD LACIE countries will be required. These data will be in the form of map overlays suitable for use with USAF ONC's (Required by YES; Category 2; Implementation Responsibility: DAPTS/USDA).

5.1.1.5.7 Boundaries of political subdivisions: Boundaries of smallest political subdivisions, and boundaries of TBD agricultural reporting areas are required. Crop calendars as a function of TBD agricultural reporting districts for TBD LACIE countries are to be included in this data package (Required by YES; Category 2; Implementation Responsibility: DAPTS/USDA).

5.1.1.5.8 LACIE maps: Maps of all LACIE countries in a 1:1,000,000 scale TBD projection for the identification of strata, zones and regions are required (Required by YES; Category 2; Implementation Responsibility: DAPTS/FSO).

5.1.1.5.9 Agricultural reports: Reports generated by the United States Department of Agriculture/Foreign Agricultural Services (USDA/FAS) and any publication from a LACIE country containing current information on wheat acreage, yield, and production will be required. These data will be used to maintain the current sampling strategy (Required by YES; Category 1; Implementation Responsibility: DAPTS/USDA).

5.1.1.5.10 Spring and Winter Wheat Growth Stage Dates: (Required by YES Category 1; Implementation Responsibility: DAPTS/USDA.) To insure an adequate agricultural data base for tests of the adjustable crop calendar and the adjustable crop calendar starter model the following data on dates when the crop reaches a certain stage of development will be required. These dates are required for spring and winter

wheat (separately) where they co-exist in the following locations: (1) all Intensive Test Sites; (2) Texas CRD's IN, IS, 2 N&S, 5 N&S, 8 N&S; (3) Kansas-all CRD's; (4) North Dakota-all CRD's; (5) Montana-CRD 1, 2, & 3; (6) Foreign areas where available.

The dates are required when the growth stages (as described in Appendixes A, B and C) are as follows: (1) 50% of fields are planted; (2) 50% of fields are emerged; (3) 50% of the fields have started to joint; (4) 50% of the fields have started to head; (5) 50% of the fields have reached soft dough (start to turn color); (6) 50% of the fields are ripe (hard dough); (7) 50% of the fields are harvested. In addition to the above, 10% and 90% dates for (1) through (7) are required for all Intensive Test Sites.

To operate the adjustable crop calendar (as a backup starter) the following information is required: (1) For winter wheat in each CRD in LACIE where a winter wheat sample segment exists (see Appendix D for states in which winter wheat sample segments exist) and in LACIE foreign areas where available, the date 50% of the crop has been planted and the date 50% of the crop has begun to joint. (2) For spring wheat in each CRD in LACIE where a spring wheat sample segment exists (see Appendix D for states in which spring wheat sample segments exist) and in LACIE foreign areas where available the date 50% of the crop has been planted.

Appendix E contains the suggested data formats for 50%, 10% and 90% growth stage dates reports.

This information is required from the crop year starting October 1974 to 1975 and each year for the duration of the LACIE program.

5.1.2 Classification and Mensuration Subsystem (CAMS)

5.1.2.1 Sample segment statistics. For research into and testing of signature extension and boundary definition during Phases I and II, access to the statistics generated by CAMS for some areas of wheat will be required. This is not required in real-time, however (Required by YES; Category 3; Implementation Responsibility: CAMS).

5.1.3 Yield Estimation Subsystem (YES)

5.1.3.1 Yield model programs. During Phase I it is required that programs for operating the yield models described in section 4.0 be prepared and tested for Phase II use (Required by YES; Implementation Responsibility: YES/NOAA).

5.1.3.2 Meteorological data requirements.

5.1.3.2.1 Meteorological flags. During Phase I is is required that meteorological flags be defined for conditions favoring spread of disease or for catastrophic events for Phase II use (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

5.1.3.2.2 Meteorological data. Development of yield models by regression equations and determinations of variations in crop progression as a function of weather conditions are required for all phases of LACIE. Thus, climatic data must be acquired for all stations of record within the wheat-growing regions of each LACIE country.

These records should include, as a minimum, monthly average of daily maximum and minimum temperatures and precipitation amounts for the periods of wheat yield records in that area. Where available, the record may contain more temporal detail and other parameters. Examples of parameters that may be available are average daily maximum temperature, average daily minimum temperature, monthly mean rainfall, daily rainfall reports, snowcover, drought index, and solar radiation.

Meteorological stations from which data are required are all those in each smallest political subdivision containing one or more LACIE sample segments. It is anticipated that up to 5000 meteorological stations may be involved. These records are required in either published volumes or on computer-compatible magnetic tape.

Once monthly NOAA will deliver to NASA-JSC-NOAA/YES the daily transmission plus a monthly summary of the WMO data received and transmitted daily. This is required on magnetic tape in the formats of Appendixes F and G. (Required by YES; Category 1; Implementation Responsibility: YES/NOAA).

5.1.3.2.3 Meteorological satellite data. A comprehensive description of the meteorological conditions over sparse areas of routinely acquired data must be provided. Thus, procedures using meteorological satellite data operationally to complement the surface data must be devised. This development will require the acquisition of daily meteorological satellite data for selected areas, both in the visible and thermal infrared. The parameters to be considered, the presentation format, frequency of acquisition, and operational system need dates are TBD. (Req.'d by YES; Cat. 2; Impl. Resp.: YES/NOAA).

5.1.3.3 Yield coefficients. During Phase I, for Phase II use, it is required that coefficients be determined for each yield stratum (for as many as 100 yield strata) for each variable (up to eight variables), for as many as five periods in the growing season. The specific forms of the coefficients and the specific variables which they modify will be dependent on model choice. This will be accomplished at Columbia, Missouri (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

5.1.3.4 Crop calendar adjustment algorithms. During Phase I and II, algorithms for adjusting crop calendars to account for meteorological conditions will be required. In Phase I, these may be in very simple form and applicable only to areas where samples are acquired. A more comprehensive approach is anticipated in Phase II (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

5.1.4 Crop Assessment Subsystem (CAS)

5.1.4.1 Yield prediction or production feedback. In Phase II, it will be required that the CAS provide YES with appropriate data concerning yield or production estimates deviating more than 15 percent from means. This may be based on reports not generally available to YES. Significant departures from surrounding stations estimates will also be flagged (Required by YES; Category 2; Implementation Responsibility: CAS).

5.1.4.2 Yield prediction point definition. Definition of the geographic points for which yield forecasts must be made will be necessary (Required by YES; Category 1; Implementation Responsibility: CAS).

5.1.5 Integrated Storage, Retrieval, and Reformatting Subsystem (ISRRS)

Prior to the commencement of Phase II, a system for receiving, buffering, storing, and indexing daily electronic real-time meteorological data must be designated, tested, and implemented. The system should be designated to accommodate daily imputs from all (up to 5,000) stations with as many as eight variables from each. A tap on the international weather network must be designed to acquire this data. The most logical location of this tap is at Suitland, Maryland. Since all stations and parameters on the international network are not stored at Suitland, planning to acquire these data out of the current Suitland files does not seem feasible. Once it is acquired the daily data will necessarily be transmitted to the points of model operation. Transmission of data will probably be by surface teletype line. Requirements for acquisition and transmission are defined in section 5.1.5.1.

5.1.5.1 Data input system. A system for receiving and buffering these data at the points of acquisition and model operation is required. The design must be based on the type of transmission system used and on the computer which will be used to process the data (Required by YES; Category 2; Implementation Responsibility: ISRRS).

5.1.5.2 Data storage system. After receipt and buffering, the real-time meteorological data must be stored for recall (within 2-hours) upon demand (Required by YES; Category 2; Implementation Responsibility: ISRRS).

5.1.5.3 Model storage and operation. Models to be used in yield computations and their coefficients must be stored for recall (within 2-hours) upon demand. The models and coefficients will be called by yield strata. The data will be called by individual stations for a period of time up to 30 days at one yield prediction update interaction. There will be requirements for storage of the models (subscripted to n strata), coefficients (subscripted to n strata, m variables, s stations, and d dates), where $n = 100$, $m = 8$, $p = 5$, $s = 5{,}000$, and $d = 365$. A cross-referenced index between yield strata, station, number, and station location should be kept in storage for immediate recall (Required by YES; Category 2; Implementation Responsibility: ISRRS).

5.1.5.4 Crop calendar storage and operation. The adjustable crop calendar model will require access to the stored meteorological data and access to the basic crop calendar upon demand (within 2-hours). The basic crop calendar will be subscripted by yield strata, crop identification, and station number. For wheat, the calendar will consist of calendar day, phase of growth (numerical scale), up to three different growth indices corresponding to those phases of plant growth, and the standard deviation of that phase of growth in days. For crops other than wheat, the calendar will consist of day of year, phase of growth of wheat (numerical scale), and phase of growth of other crops (Required by YES; Category 2; Implementation Responsibility: ISRRS).

5.1.5.5 Nonelectronic data storage and recall - YES. It is required that historic yield and meteorological data received in the form of printed volumes be indexed by content and stored for recall (within 2-hours) upon demand (Required by YES; Category 2; Implementation Responsibility: ISRRS).

5.1.6 System Performance Evaluation (SPE)

5.1.6.1 Cost effectiveness determination - YES. YES requires the definition of the specific data needed to perform the efficiency analysis for this, along with expert assistance in designing the procedures to perform this operation (Required by YES; Category 3; Implementation Responsibility: SPE).

5.1.7 Information Evaluation (IE)

There is no input requirement involving Information Evaluation (IE).

5.1.8 Research

The YES will require the following inputs from research.

5.1.8.1 Yield models. Yield models and programs that can use standard and predicted meteorological data as input

must be specified. Such models and programs must predict wheat yield at harvest during the growing season for points in the wheat growing regions. These specifications will be needed prior to the start of Phase II (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

5.1.8.2 Model boundary definition. Boundaries of applicability of the models described in section 5.1.8.1 must be defined prior to the start of Phase II (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

5.1.8.3 Wheat growth indices. Indices for wheat growth that define the stage of crop development in terms of environment the plant experiences will be required (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

5.1.8.4 Meteorological satellite procedures. Procedures for deriving surface weather input variables for yield models from environmental satellite data will be required (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

5.1.8.5 Relation of phenological development to yield. Procedures for relating phenological development to yield will be required (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

5.1.8.6 Relation of spectral appearance to plant condition. Procedures for relating spectral appearance of wheat and confusion crop by remote observations to stage of development, stand, and freedom from stress will be required (Required by YES; Category 2; Implementation Responsibility: YES/NASA-RTEB).

5.1.9 Test and Evaluation

The YES will require the following inputs from test and evaluation.

5.1.9.1 Test of appearance versus yield procedures. Procedures for relating wheat yield to appearance must be tested and the results input to the YES (Required by YES; Category 2; Implementation Responsibility: YES/NASA-RTEB).

5.1.9.2 Yield model sensitivity test. The sensitivity of yield models to detail in the input meteorological data must be tested and the results input to the YES (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

5.1.9.3 Yield model comparison tests. Comparative test of yield models must be performed and the results input to the YES (Required by YES; Category 2; Implementation Responsibility: NASA-RTEB).

5.1.9.4 Test of meteorological satellite data utility. The utility of meteorological satellite data to the YES must be determined and the results input (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

5.2 INTERIM SYSTEMS

During Phase I, YES will require an historic data base which allows planning of ERTS data acquisition. This will consist of mean crop calendars for wheat, small grains, and other dominant crops for all countries involved in the study. These calendars will be required by January 1, 1975 for the areas to be considered in Phase I (Required by YES; Category 2; Implementation Responsibility: DAPTS/USDA).

During Phase I real time meteorological data will be required for test purposes in all countries, but not necessarily on a current basis. Data systems should be implemented as follows:

- For Canada and U.S.A. by March 1, 1975
- For the U.S.S.R. and China by June 1, 1975
- For other countries by July 1, 1975

Data recall capability will be provided to September 1, 1974. On a world-wide basis, up to 5,000 stations will be identified with as many as eight variables, including daily maximum temperatures, daily minimum temperatures, daily rainfall, and others (Required by YES; Category 2; Implementation Responsibility: DAPTS/NOAA).

6.0 SUBSYSTEM OUTPUT REQUIREMENTS

6.1 FULL-UP SYSTEM

6.1.1 YES Outputs Required by DAPTS

6.1.1.1 ERTS data requirements - biological windows. Specific biological windows for the 4800 sample areas in the format specified in the GSFC/JSC Interface Control Document (ICD) for LACIE will be required. This output will be transmitted via the CAMS and Information Storage, Retrieval, Reformatting Subsystem (ISRRS) for DAPTS action (i.e., CAMS must concur on YES output) (Required by DAPTS; Category 1; Implementation Responsibility: YES and CAMS).

6.1.1.2 Field data requirements. No requirements from YES output.

6.1.1.3 Historical agricultural data requirements. No requirements from YES output.

6.1.2 YES Outputs Required by CAMS

6.1.2.1 Acquisition windows. Utilizing desired acquisition windows defined by CAS in terms of crop growth stages, YES will estimate the dates which correspond to the growth stages defined in terms of crop phenology records and models, historical meteorological data, and/or other information. Initial windows are provided to CAMS at the beginning of the crop year, based on historical data. They are updated as required by real-time data and are transmitted to DAPTS through ISRRS with CAMS concurrence (Required by CAMS; Category 1; Implementation Responsibility: YES/NOAA).

6.1.2.2 Crop calendars. YES will acquire crop calendars through DAPTS/USDA for each potential training sample segment which will support the image interpretation. These crop calendars, in the form of bar graphs will be based on historical data and will provide the periods of seedbed preparation, planting, phenological growth stages, and harvesting of the crop types within a specified region. The earliest date, the latest date and the period in time when approximately 50 percent of a given crop is in a defined stage will be provided for each field condition or biological stage. This type of calendar will be provided for wheat, its confusion crops (small grains), and all other crops which taken together constitute 95 percent of the total cultivated acreage in a region. Tabular updates to the bar graphs will be provided throughout the growing season to indicate the deviation (either early or late attainment of various growth stages of wheat) in response to real-time meteorological data (Required by CAMS and CAS; Category 1; Implementation Responsibility: YES/NOAA).

6.1.2.3 Meteorological summary. Meteorological data will also be utilized to provide biweekly updates of the weather being experienced in specific regions. Such data will be similar to that being provided for the United States in the Weekly Weather and Crop Bulletin; i.e., normal moisture and temperature, wetter and warmer than normal, drier and warmer than normal, and drier and cooler than normal. These data will be provided in tabulations which will consider sample segments as contours on a ration of one to one million overlays suitable for use with United States Air Force Operational Navigational Charts (USAF-ONC). A narrative, which would flag areas where signature extension might not be successful due to some parameter other than temperature and/or precipitation, will also accompany the above. Such other parameters include wind damage, hail damage, insect and disease loss or other anomalies occurring within the yield strata (Required by CAMS and CAS; Category 1; Implementation Responsibility: YES/NOAA).

6.1.3 YES Outputs Required by YES

6.1.3.1 Crop calendars. YES will utilize crop calendar output required by CAMS and CAS and described in section 6.1.2.2 to improve yield models generated by YES/NOAA (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

6.1.3.2 Yield predictions. YES will require access to all previous predictions of yield and crop calendar adjustments (within 2-hours) upon demand (Required by YES; Category 1; Implementation Responsibility: YES/NOAA).

6.1.3.3 Meteorological data. Development of yield models by regression equations and determinations of variations in crop progression as a function of weather conditions are required for all phases of LACIE. Thus, climatic data must be acquired for all stations of record within the wheat-growing regions of each LACIE country.

These records should include, as a minimum, monthly average of daily maximum and minimum temperatures and precipitation amounts for the periods of wheat yield records in that area. Where available, the record may contain more temporal detail and other parameters. Examples of parameters that may be available are average daily maximum temperature, average daily minimum temperature, monthly mean rainfall, daily rainfall reports, snowcover, drought index, and solar radiation.

Meteorological stations from which data are required are all those in each smallest political subdivision containing one or more LACIE sample segments. It is anticipated that up to 500 meteorological stations may be involved. These records are required in either published volumes or on computer-compatible magnetic tape.

Once monthly NOAA will deliver to NASA-JSC-NOAA/YES the daily transmission plus a monthly summary of the WMO data received and transmitted daily. This is required on magnetic tape in the formats of Appendixes F and G. (Required by YES; Category 1; Implementation Responsibility: YES/NOAA).

6.1.3.4 Meteorological satellite data. A comprehensive description of the meteorological conditions over sparse areas of routinely acquired data must be provided. Thus, procedures using meteorological satellite data operationally to complement the surface data must be devised. This development will require the acquisition of daily meteorological satellite data for selected areas, both in the visible and thermal infrared. The parameters to be considered, the presentation format, frequency of

acquisition, and operational system need dates are TBD. (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

6.1.3.5 Meteorological data. Current standard meteorological data is required for use by the CAS analyst in accounting for episodal weather events in crop aggregations and for analysis of crop production.

These records should include, as a minimum, monthly average of daily maximum and minimum temperatures and percipitation amounts for the periods of wheat yield records in that area. Where available, the record may contain more temporal detail and other parameters. Examples of parameters that may be available are average daily maximum temperature, average daily minimum temperature, monthly mean rainfall, daily rainfall reports, snowcover, drought index, and solar radiation.

Meteorological stations from which data are required are all those in each smallest political subdivision containing one or more LACIE sample segments. It is anticipated that up to 5000 meteorological stations may be involved. These records are required in either published volumes or on computer-compatible magnetic tape.

Once monthly NOAA will deliver to NASA-JSC-NOAA/YES the daily transmission plus a monthly summary of the WMO data received and transmitted daily. This is required on magnetic tape in the formats of Appendixes F and G. (Required by CAS; Category 1; Implementation Responsibility: YES/NOAA).

6.1.4 YES Outputs Required by CAS

6.1.4.1 Crop calendars. Crop calendars and real-time adjustments to crop calendars by strata, such as delays in planting, abnormal end of dormancy in spring, plus output described in section 6.1.2.3, will be provided to CAS (Required by CAS; Category 1; Implementation Responsibility: YES/NOAA).

6.1.4.2 Meteorological summary. Tabulations, overlay maps, and narratives will be provided to CAS and CAMS to provide an overall view of the prevailing meteorological conditions and annotations, whether normal, above normal, or below normal, and to what extent. Flags shall be provided to CAS for aggregate consideration and to CAMS for consideration of signature extension on the amount of strata, zone, region, or country which has experienced abnormal weather (unseasonably high or low temperatures, precipitation, storms, etc.) (Required by CAS and CAMS; Category 2; Implementation Responsibility: YES/NOAA).

6.1.4.3 Electronic data. Yes will provide CAS with the following electronic data:

6.1.4.3.1 Meteorological stations: YES will give locations of meteorological stations, including: stratum identification and latitude and longitude in degrees and minutes plus yield strata descriptors (Required by CAS; Category 2; Implementation Responsibility: YES/NOAA).

6.1.4.3.2 Yield coefficient definitions: YES will provide CAS with yield coefficients for spring and winter wheat in each yield stratum and confidence limits on estimates derived. One thousand WMO stations and 100 yield strata will be required monthly (Required by CAS; Category 2; Implementation Responsibility: YES/NOAA).

6.1.4.3.3 Yield strata boundaries: YES will provide CAS with a description and $1:10^6$ ONC map of the boundaries of yield strata for all LACIE countries (Required by CAS; Category 1; Implementation Responsibility: YES/NOAA).

6.1.4.4 Yield values. Supply yield values and confidence limits for each meteorological station and designated points within each yield stratum on a monthly basis (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

6.1.4.5 Yield accuracy. The YES will provide yield estimates for each yield stratum along with yield coef-

ficients, f value for each coefficient and correlation coefficient for each variable, standard deviation for each variable, and number of samples used for each yield stratum (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

6.1.4.6 Historical yield data. YES will provide, based on historical data, the expected yield and associated variance for each area for which yield estimates are made (Required by CAS; Category 3; Implementation Responsibility: YES/NOAA).

6.1.5 YES Outputs Required by ISRRS

Since the ISRRS stores, reformats, and retrieves data required and produces YES (as well as other subsystems), the requirements for storage of YES outputs have been described in sections 4.0 and 5.0 of this document. All YES outputs are to be accessible at least monthly and (within 2-hours) upon demand (Required by ISRRS; Category 1; Implementation Responsibility: YES/NOAA).

6.1.6 YES Outputs Required by SPE

Information on resources expended in the collection, processing, and delivery of meteorological data to JSC is required on an as-requested basis. (Required by SPE-EA; Category 1; Implementation Responsibility: YES/NOAA).

6.1.7 YES Outputs Required by IE

No YES outputs are required by IE.

6.1.8 YES Outputs Required by Research

A. Three sets of data listing historical daily maximum and minimum temperatures, precipitation, and solar radiation (as wheat-growing areas of all

LACIE countries). These data will be provided on standard WMO computer-compatible tapes.

B. One set of record of daily climatic values of maximum and minimum temperatures and rainfall reports for U.S. stations (St. Cloud, Minn.; Billings, Glasgow, Great Falls, Harve, and Miles City, Montana; Bismark, Fargo, and Williston, North Dakota; Aberdeen, Huron, Rapid City, and Sioux Falls, South Dakota; and Sheriden, Wyoming) for the period 1950-1974. These data may be in tabular form or on CCT.

C. One set of climatological data at 6-hour intervals for the 1950-1974 period for temperature, dew point, windspeed, cloud type, and amount for Great Falls, Montana; Fargo and Williston, North Dakota; and Aberdeen, South Dakota (as available); monthly data for precipitation and evaporation for Minnesota and North and South Dakota. These data may be in tabular form or on CCT. (Required by Research; Category 1; Implementation Responsibility: YES/NOAA).

6.1.9 YES Outputs Required by Test and Evaluation

6.1.9.1 Acquisition windows. Phenological descriptions and updates as described in 6.1.2.1 and 6.1.2.2 will be provided to T&E.

6.2 INTERIM SYSTEM CROP CALENDAR

CAMS, CAS, and DAPTS require that YES provide guidance as to when to acquire ERTS samples based on mean crop calendars for the sample areas. YES will also provide subjective adjustments based on meteorological conditions up to the time of prediction of departure from normal (Required by CAMS, CAS, and DAPTS; Category 2; Implementation Responsibility: YES/NOAA).

7.0 INTERFACE REQUIREMENTS

An interface control document is required between NOAA, USDA, and NASA to define in detail the responsibility of each agency to the project, the schedule by which those responsibilities will be met, identification of the points of interface, and the design of those interfaces. Particular emphasis is given to the subjects of:

- Responsibility for input data acquisition, transmission, and format specifications
- Responsibility for determining the effects of cloud cover on data acquisition
- Responsibility for the design and operation of adjustable crop calendars
- Responsibility for research in the use of meteorological satellite data for input into yield prediction
- Responsibility for development of remote sensing detection of wheat yield anomalies

8.0 OPERATIONAL REQUIREMENTS

Operational requirements have been stated in earlier sections and are summarized in the following paragraphs.

8.1 THROUGHPUT REQUIREMENTS

Yield predictions for up to 5,000 points will be updated monthly and on demand. This will require throughput of up to eight daily values from each of the 1,000 meteorological stations. Crop calendar updates for up to 500 points will be required monthly and on demand.

8.2 RESPONSE REQUIREMENTS

Crop calendar updates on a world wide basis with one week's notice should be provided to accommodate demands for yield predictions. YES will require access to all ISRRS stored data, and programs must be supplied within 2-hours.

8.3 RELIABILITY REQUIREMENTS

Reliability requirements have not yet been established.

8.4 SECURITY REQUIREMENTS

Security requirements have not yet been established; however, a LACIE Security Plan shall be prepared by each organization designated with implementation responsibility. The plan for each implementing organization shall define the specific measures that will be utilized by that organization to comply with the LACIE security requirements. The LACIE security requirements shall be defined by the USDA and will be forwarded to the implementing organizations upon receipt by the LACIE Project Manager. Each implementing organization shall submit a plan for approval to the LACIE Level III Change Board within 90 days after receipt of the USDA requirements.

8.5 DELIVERY REQUIREMENTS

Daily meteorological data must be received in a timely but efficient manner. It is anticipated that data will be transmitted by teletype landlines.

8.6 QUALITY ASSURANCE REQUIREMENTS

8.6.1 Quality Assurance Plan

A LACIE Quality Assurance (QA) Plan shall be prepared by each organization designated with implementation responsibility. The plan shall cover a complete definition of all quality assurance functions that will be implemented to assure maintenance of adequate quality levels during operations. The plans shall be submitted to the LACIE Level III Change Board for approval within 90 days after the requirements documents are baselined.

8.6.2 Problem/Defect Reporting

The existing Discrepancy Report (DR) is sufficient for reporting problem/defects within the system.

8.6.3 Stop-Work Orders

When a unit has developed a major problem and is consistently producing an inferior product, more drastic action is required. A "Stop-Work Order" would be issued by the QA group based upon inspection of the product defect as reported by a PDR or by inspection of a line or benchmark test. The Stop-Work Order would be signed by the respective QA, operations, and unit managers. As a result, all operations in the affected area would stop immediately until the problem is corrected. The system would remain in a down condition until QA is satisfied, based upon a line test or benchmark test indicating that the system is capable of continuing its operations. At that time the

stop-Work Order would be formally lifted by the aforementioned managers, or at least the system would be put into a "conditional restart" mode, pending inspection of the first product produced.

8.6.4 Verification of Operational Readiness

One major task of the QA group would be to verify daily the operational readiness of all units in the system. All subsystems should run a benchmark test before beginning daily operations, and the Production Film Converter (PFC) should run a line test at least daily. It would be the QA group's responsibility to ensure that the tests are run, to read the output of the tests, and to give a go or no-go to each subsystem.

9.0 SUBSYSTEM VERIFICATION REQUIREMENTS

Each organization designated with implementation responsibility shall prepare a LACIE Verification Plan. Each plan shall include a complete definition of the functions proposed for verification of the portion of LACIE for which each organization is responsible. Each organization shall submit its plan to the LACIE Level III Change Board for approval within 90 days after the requirements documents are baselined. The verification plans shall include, as a minimum, the following items related to the YES subsystem:

- Yield models must be tested for consistency of performance. The U.S.A. and Canada models must be subjected to such tests by May 1, 1975. Models for all countries must be tested by September 1, 1975 (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

- Crop calendar adjustment accuracy must be tested during and after Phase I operations. This will involve the field data, intensive test site data, and perhaps other surface ground truth (Required by YES; Category 2; Implementation Responsibility: YES/NOAA/USDA/NASA).

10.0 RESEARCH REQUIREMENTS

The YES requires that the following research be conducted:

10.1 SELECTION OF MODELS

Wheat yield models which express the cause and effect relationship between weather and grain production as accurately as possible should be selected or developed. The models should use input data which are universally available. To the extent that no one general model will yet be devised, individual models or variations will be developed for specific areas and specific growing conditions. The input data can include maximum and minimum air temperatures, daily total precipitation, and such other surface weather observations (evaporation for example) as can be acquired. Input data may also include soil water capacity in the wheat root zone, satellite measurements of wetted area after rainfall, area under snowcover, estimated radiation from knowledge of cloud cover, and, eventually, derived surface air temperatures and estimated precipitation amounts integrated over large areas (one or more U.S.A. counties perhaps) (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

10.2 IDENTIFICATION OF YIELD STRATA

Yield strata should be defined and identified so that within each stratum, cultural, and environmental factors are essentially uniform (Required by CAS/YES; Category 1; Implementation Responsibility: YES/NOAA).

10.3 TESTING AND COMPARISON OF MODELS

Models should be tested and compared and the best model selected currently for each stratum (Hopefully, one model will be adequate for many strata) (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

10.4 SELECTION OF HISTORICAL DATA

The historical data most representative of current conditions should be selected and constants computed for use in operational models (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

10.5 SELECTION OF OPERATIONAL MODELS

Selected operational models, including required constants, should be programmed and tested on computer(s) to be used by the operational system, with input data from current WMO network weather stations (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

10.6 IDENTIFICATION OF CROP CALENDAR

The phenological development of cereal crops, particularly wheat, should be defined in terms of a "crop calendar" which relates a sum of calculated weather units to an attained stage of crop development. This crop calendar should be as universally adapted to differences in latitude and altitude as possible and should be consistent within a given variety of wheat. Not only mean dates of attaining given stages of development and the standard deviation of these mean phenological dates are required, but the percentage of acreage reaching a given phenological stage on a specific date should be described (Required by YES; Category 2; Implementation Responsibility: YES/NOAA/USDA).

10.7 DERIVATION OF SURFACE WEATHER VARIABLES FROM SATELLITE DATA

Surface weather input variables for yield models must be derived from environmental satellite data (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

10.8 COMPARISON OF PHENOLOGICAL DEVELOPMENT TO YIELD

The relationship between phenological development and yield should be identified (Required by YES; Category 3; Implementation Responsibility: YES/NOAA).

10.9 OTHER COMPARISON FACTORS

The spectral appearance of wheat and confusion crops should be compared with and related to phenological stages of development, vigor and density of stand, freedom from stress such as drought, disease and insects, flood, wind, winter-kill, and potential yield (Required by YES; Category 2; Implementation Responsibility: YES/NASA-Science and Applications Directorate (S&AD)-RTEB).

10.10 RESEARCH PERFORMANCE REQUIREMENTS

It is anticipated that as a minimum the following historical and in situ data will be required to perform the research described here.

- In Phases I and II, an inventory should be made of meteorological/climatic data and the available wheat yields in the wheat growing regions. These data should be broken down to the most detailed available level of record for use in selection of models and for requesting data to be used in computation of yield coefficients in the models chosen.

- Pertinent historical meteorological observations should be acquired over n years of record so stations can be specified at a frequency adequate for developing coefficients for the models to be used in the area of interest.

- Information should be gathered on historical wheat yields and phenological records over n years with as fine detail as can be achieved consistently.

- Measurements should be taken of the Haun Index and other phenological data at each intensive test site throughout the 1974-75 season at intervals to be determined (TBD).

- Leaf area index measurements should be taken at TBD intensive test sites throughout the 1974-75 growing season.

- Yield measurements should be made of 1974-75 wheat in intensive test sites.

- Spectral signatures should be acquired from the S191H Helicopter System at TBD intervals under TBD conditions throughout 1974-75 growing season in TBD intensive test sites.

- Data should be consolidated and distributed as rapidly as possible to research and testing investigators of all spectral, morphological, or meteorological measurements acquired in intensive test sites.

11.0 TEST AND EVALUATION REQUIREMENTS

The YES requires that the following testing and evaluation be performed:

- Early in Phase I of the project, the pilot effort will be required to provide a plan acceptable to YES for testing the procedures for relating wheat yield to appearance. This effort includes the application of ERTS data over intensive test sites and other TBD areas arrived at in the research effort (Required by YES; Category 2; Implementation Responsibility: NASA-S&AD-RTEB).

- During Phases I and II, the pilot effort will be required to test according to plan the procedures for relating wheat yield to appearance, using ERTS data acquired over the intensive test sites and other TBD areas (Required by YES; Category 2; Implementation Responsibility: NASA/JSC).

- In Phases I and II, the YES will require the pilot effort to plan and implement tests of the sensitivity of the model(s) to the available detail in the meteorological information. It is anticipated that this will require measurement of TBD environmental parameters over the intensive test sites at a TBD frequency (Required by YES; Category 3; Implementation Responsibility: ---).

- During Phase I, YES will require the pilot effort to test and compare the yield models considered for selected regions and, in doing so, will exercise where feasible the application system for LACIE yield, to test and improve upon its design (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

- During Phases I and II, YES will require the pilot effort to determine the utility of meteorological satellite data to the project, using techniques acquired during research and development (Required by YES; Category 2; Implementation Responsibility: TBD in the ICD).

- During Phases I and II, YES will require an ongoing effort to test and compare its yield prediction methods with other possible methods (Required by YES; Category 2; Implementation Responsibility: YES/NOAA).

APPENDIX A
DEFINITION OF WHEAT GROWTH STAGES

Emerged* - Is defined as indicated by Stage 1 of figure B-1 where there is only one shoot. This is prior to tillering and prior to Code 1, Pre-Flag, of Appendix C (extract from Enumerator's Manual, 1974 Wheat Objective Yield Survey).

Jointed* - Is defined as indicated by Stage 6 of figure B-1 where first node of the stem is visible. This stage is also prior to Code 1, Pre-Flag, of Appendix C (extract from Enumerator's Manual, 1974 Wheat Objective Yield Survey).

Heading* - Is defined as indicated by Stage 10.1 of figure B-1 and is equivalent to Code 3, Late Boot or Flower (Heads Emerged) includes Watery Kernels, of Appendix C (extract from Enumerator's Manual, 1974 Wheat Objective Yield Survey).

Soft Dough* - Is defined as indicated by Stage 11+ of figure B-1 and is equivalent to Code 5 of Appendix C (extract from Enumerator's Manual, 1974 Wheat Objective Yield Survey).

Hard Dough* - Is defined as Code 6 of Appendix C (extract from Enumerator's Manual, 1974 Wheat Objective Yield Survey).

Harvest of Harvestable* - Is defined as Code 7 of Appendix C (extract from Enumerator's Manual, 1974 Wheat Objective Yield Survey).

*NOTE: There will be cases when the observer will be undecided on the growth stage (i.e., maturity stage) of the field. When this occurs, review the growth stages (maturity stages) involved and classify the unit in the stage that it most nearly represents. If still undecided, classify it in the lower stage of growth (maturity).

APPENDIX B

ILLUSTRATION OF THE FEEKES SCALE

Figure B-1 is an illustration of the Feekes Scale.

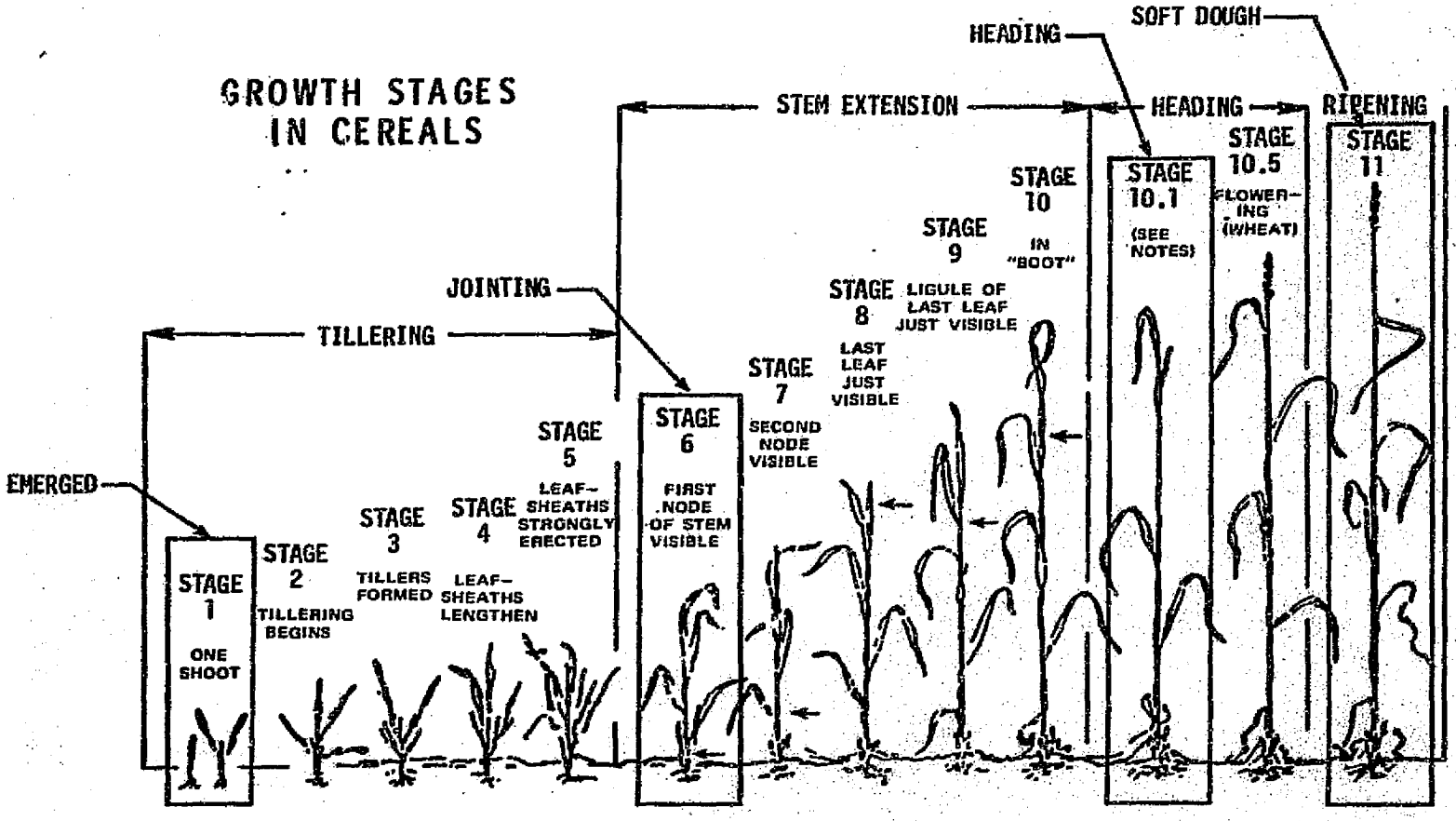

Figure B-1.- Illustration of the Feekes Scale.

From E. C. Large, Growth Stages in Cereals. Plant Path. 3:128-129. 1954.

APPENDIX C
EXTRACT FROM ENUMERATOR'S MANUAL
1974 WHEAT OBJECTIVE YIELD SURVEY

Item 2 - Stage of Maturity
A stage of maturity is to be assigned each unit by circling the numerical stage code in the Item 2 table. The stage which you assign the unit should be the same as that of the greatest number of stalks inside the unit. Do not damage any plants in the unit. Where some plants in the field have started to head, examine a few heads outside the unit to assist you in determining the maturity. Use the descriptive material below and on the back cover as criteria for arriving at the stages of maturity. There will be cases when you are undecided on the maturity stage of the unit. When this occurs, review the maturity stages involved and classify the unit in the stages that it most nearly represents. If still undecided, classify it, in the lower stage of maturity.

Maturity Stages:

Code 1 - Pre-Flag
This is a general category in which you will record all units where tillers are only an inch or two high, up to units where stalks are large or mature enough to be in the "Boot" stage. The stalks do not indicate any swelling and do not have the definite flag leaf or other evidence of a partly developed head inside the leaf sheath.

Code 2 - Flag or Early Boot
Stalks are starting to joint and joints can be seen easily. The plant has four or five leaves and the "flag leaf" is identifiable and its collar is visible above the top foliage leaf. A partly developed head may be detected by noting that the steam has started swelling below the top foliage leaf. This swelling may also be felt inside the sheath. Be careful not to damage the partly developed head by squeezing the stem of sheath.

In most cases the presence of heads enclosed in the leaf sheath could be verified by going outside the unit. Examine stalks that are similar in appearance to the doubtful ones before classifying the unit in the FLAG or EARLY BOOT stage. Clip a few stalks, unroll the leaf sheath and see whether or not there is a small, partially developed head encased in the sheath.

Code 3 - Late Boot or Flower (Heads Emerged)
Includes Watery Kernels
The head has moved up in the stem so that some swelling has occurred above the base of the top foliage leaf. The sheath will split shortly after the "Late Boot" stage and the head will partially or wholly emerge. The flower stage occurs soon after the head emerges. Small blooms or flowers begin to open at the base of the head and blooming progresses toward the tip. For our purpose, consider the unit to be in the late boot or flower stage from the time swelling can be seen or felt above the top foliage leaf until the watery clear liquid in the kernel has begun to turn milky.

Code 4 - Milk
Kernels are formed in heads. Kernels of grain are soft, moist and milky. When the grain is squeezed, a milky liquid can be observed. The plant is still generally green. One of two of the lower leaves may be dead, but the three upper leaves and the head are green. Signs of ripening (yellow spots or stripes) are visible only on the edges or tips of the leaves.

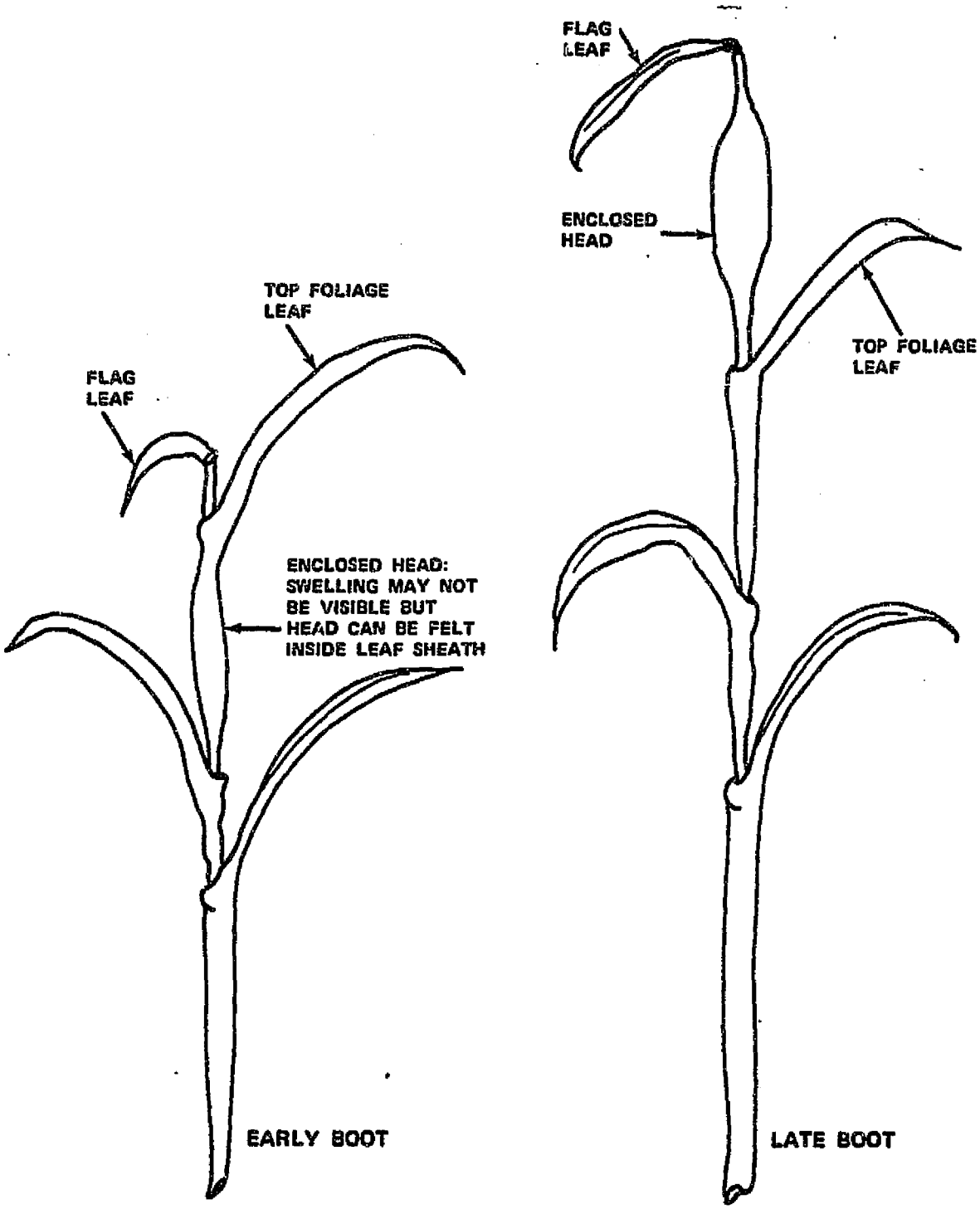

Figure C-1.- Classifying heads in "early boot" and "late boot" stages of maturity.

Code 5 - Soft Dough
The grains can be crushed between the thumb and fingernail; the contents of most of the grains are soft and can be kneaded like dough with only a few grains per head containing any milky liquid. The plant has changed to a golden tint (except in the purple-strawed types which are a pinkish purple color); the stalk is smooth and shiny, tough and pliable. Only the uppermost leaves are swollen and green, the lower leaves being shrunken and brownish.

Code 6 - Hard Dough
The grains readily part from the head and are likely to shake out of the glumes. The grain is firm and though it may be dented by pressure of the thumbnail, it is not easily crushed. The characteristic color of the grain has become more distinct. The yellow grains are paler, the red grains somewhat darker and flinty or mealy in character. The leaves are brown, dry and shrunken. Wheat in this category may be swathed in some areas.

Code 7 - Ripe
Straw is dull and brittle at this stage; the grain is hard and breaks in fragments when crushed. Harvest may be expected at this time.

Counts of Stalks and Heads Within Count Area:

APPENDIX D
STATES IN WHICH WINTER AND SPRING WHEAT SAMPLE SEGMENTS EXIST

STATES IN WHICH WINTER WHEAT SAMPLE SEGMENTS EXIST

Arizona
Arkansas
California
Colorado
Idaho
Indiana
Kansas
Maryland
Missouri
Montana
Nebraska
Oklahoma
Pennsylvania
South Dakota
Tennessee
Texas
Utah
Washington

STATES IN WHICH SPRING WHEAT SAMPLE SEGMENTS EXIST

Minnesota
Montana
North Dakota
South Dakota

APPENDIX E
SUGGESTED DATA FORMATS

The suggested data formats are as shown on the following three pages.

TABLE E-I

Check one:

☐ Spring Wheat

☐ Winter Wheat

Crop Year_____

GROWTH STAGE DATES FOR 50% DEVELOPMENT

MONTH AND DAY OF MONTH

ITS SEG. NO. -OR- STATE	CRD #	PLANTING DATE[1]	EMERGENCE DATE[1]	JOINTING DATE[2]	HEADING DATE[2]	SOFT DOUGH DATE[3]	RIPE DATE[4]	HARVEST DATE[5]

[1] Date at which 50% of fields in CRD were planted or emerged, respectively.

[2] Date at which 50% of fields in CRD had begun to joint or head, respectively.

[3] Date at which 50% of fields in CRD had begun to enter soft dough stage (turning color to greenish-yellow to yellow).

[4] Date at which 50% of fields in CRD are ripe (hard dough) stage or when they were swathed. (Indicated swathed if applicable).

[5] Date at which 50% of fields in CRD have been harvested either as standing grain or out of swath.

TABLE E-II

GROWTH STAGE DATES FOR 10% DEVELOPMENT

MONTH AND DAY OF MONTH

Check one:

☐ Spring Wheat

☐ Winter Wheat

Crop Year_____

ITS SEG. NO.	CRD #	PLANTING DATE[1]	EMERGENCE DATE[1]	JOINTING DATE[2]	HEADING DATE[2]	SOFT DOUGH DATE[3]	RIPE DATE[4]	HARVEST DATE[5]

[1] Date at which 10% of fields in CRD were planted or emerged, respectively.

[2] Date at which 10% of fields in CRD had begun to joint or head, respectively.

[3] Date at which 10% of fields in CRD had begun to enter soft dough stage (turning color to greenish-yellow to yellow).

[4] Date at which 10% of fields in CRD are ripe (hard dough) stage or when they were swathed. (Indicated swathed if applicable).

[5] Date at which 10% of fields in CRD have been harvested either as standing grain or out of swath.

TABLE E-III

Check one:

☐ Spring Wheat

☐ Winter Wheat

Crop Year_____

GROWTH STAGE DATES FOR 90% DEVELOPMENT

MONTH AND DAY OF MONTH

FIS SEG. NO. -OR- STATE	CRD #	PLANTING DATE[1]	EMERGENCE DATE[1]	JOINTING DATE[2]	HEADING DATE[2]	SOFT DOUGH DATE[3]	RIPE DATE[4]	HARVEST DATE[5]

[1] Date at which 90% of fields in CRD were planted or emerged, respectively.

[2] Date at which 90% of fields in CRD had begun to joint or head, respectively.

[3] Date at which 90% of fields in CRD had begun to enter soft dough stage (turning color to greenish-yellow to yellow).

[4] Date at which 90% of fields in CRD are ripe (hard dough) stage or when they were swathed. (Indicated swathed if applicable).

[5] Date at which 90% of fields in CRD have been harvested either as standing grain or out of swath.

APPENDIX F

FORMAT FOR CCEA DAILY WEATHER TAPES FOR U.S. AND CANADA

This is a sequential data file containing one record for each station. It is sequenced by state, crop reporting district, and synoptic station number. Each record contains station identification information; space for 31 days of data grouped minimum temperature, maximum temperature, precipitation, and degree days over 90; and summary columns. There are 140 4-byte words per record. All temperatures are degrees Fahrenheit; precipitation is in millimeters.

The tapes are IBM standard labels, 800-bpi, EBCDIC. There is a single tape mark at END OF FILE. The record format is as follows:

Word	Character Format	Contents
1	A4	2 digits state, 2 digits crop district
2	A4	1st 4 digits station number
3	A4	last digit station number and 3 digits of station code for U.S. stations
4&5	not currently used	
6	I4	minimum temperature day 1
7	I4	maximum temperature day 1
8	I4	precipitation day 1
9	I4	degree days over 90 day 1
10-129	I4	repeat of wds 6-9 for days 2-31
130	I4	during month total minimum temp., at end of month average minimum temperature
131	I4	same as minimum temp. for max. temp.
132	I4	total precipitation
133	I4	total degree days over 90
134	I4	count of days minimum temperature
135	I4	count of days of maximum temperature
136	I4	count of days precipitation
137	I4	count of days over 90
138	I4	minimum temperature flag
139	I4	maximum temperature flag
140	I4	precipitation flag

The three flag words are of no relevance once the day's data are complete. The counts are used for averaging and to have an easy reference to the amount of data in each category.

The tapes are created on an IBM 360/195. To read them on that machine, the Job Control Language (JCL) would be as follows:

```
//GO.FTxxF001  DD  DSN=CCEA.month.SRTD,DISP=OLD,
//        UNIT=TAPE9 VOL=SER=xxxxxx,LABEL=(1,SL),
//        DCB=(RECFM=FB,LRECL=560,BLKSIZE=5600,DEN=2).
```

APPENDIX G

FORMAT FOR WMO TAPE FOR OTHER COUNTRIES

This is a sequential data file. There is one record per station per recording period (i.e.: 0000, 0600, 1200, 1800) per day. The data included is block and station number, latitude, longitude, date, time, minimum temperature (if present), maximum temperature (if present), temperature at time of observation, 6-hour precipitation, present weather, past weather, and 24-hour precipitation. The sequence of the file is block and station; date, time. There are 14 4-byte words per record. It is blocked 11,200 bytes per block. It is recorded on IBM standard tapes with no label. There is a single tape mark at END OF FILE. There are two tape marks after the last file on the tape. The tapes are 9-track, 800-bpi, binary integer data.

The record format follows:

WORD	CONTENTS
1	Block and Station number
2	Latitude
3	Longitude
4	Month
5	Day
6	Year
7	Time
8	Minimum Temperature (If present)
9	Maximum Temperature (If present)
10	Temperature at time of observation
11	6 hr. Precipitation
12	Present Weather
13	Past Weather
14	24 hr. Precipitation

Temperatures are 10th of a degree Centigrade x 10
Precipitation is in millimeters

Block & Station	LAT	LONG	MONTH	DAY	YEAR	TIME	MIN	MAX	Temp at OB	6hr. PRECIP	Present Weather	Past Weather	24hr. PRECIP

The following data will be in this file:

USSR	blocks	22, 23, 26-29, 33-38
China	blocks	50-59
India	blocks	42, 43
Australia	blocks	94
Argentina	blocks	87
Brazil	blocks	82, 83

The United States and Canada will continue to be provided as in the past.

This LACIE II file will be provided twice a month. The first tape will cover the 1st through the 15th; the second tape, the 16th through the end of the month.

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